Predicting Persistence of Microbial Biocontrol Agents

Stefan Jaronski, USDA ARS NPARL, Sidney MT

There are a number of environmental factors that affect the persistence of microbial biocontrol agents. A discussion of this topic, spanning arthropod, plant and microorganism targets, is a complex subject with, perhaps, few successful generalities.

The target habitat is a strong determinant of which factors are important or not. On the phylloplane there is UV-A/UV-B radiation, rainfall, phylloplane pH, phylloplane chemistry, phylloplane microbiota, and temperature. In the soil arena, factors affecting persistence are moisture, temperature, microbiota, macrobiota, and soil chemistry (often as it affects microbiota). In aquatic habitats temperature, chemicals (e.g., organic pollutants) and physical sequestration (e.g., sedimentation, removal by currents) can be important determinants of microbe persistence. Long term persistence in all these habitats is dependent on target population or reservoir numbers, esp. if the agent does not have a sturdy resistant stage to survive absence of its host.

The transiency of the target habitat is also important. An annual crop is marked by a very finite span – weeks, perhaps a few months – and a catastrophic end at harvest. In most cases the host population vanishes. The physical habitat undergoes drastic disruption with tillage and preparation for the next crop, which is often quite different if crop rotation is practiced. In such cases, microbial agents are frequently used inundatively with little need for prolonged persistence. The biennial or perennial crop provides a slightly longer stability, but often the host population disappears for a time, having gone into diapause (insects) or resting stage (plant pathogens, weeds). Here, microbial agent persistence needs to be only through each season with the agent reapplied in the next growing season. Orchard crops, especially in subtropical and tropical climates, provide an even longer, stable habitat, but pest, weed, or plant pathogen presence can still be only transient and thus the need for a microbial control agent also needs to be transient, and persistence only moderate. Natural habitats (forests, rangelands, water bodies) can offer the most stable environments and prolonged presence of target organism, although there is often a seasonality to target host presence. Classical biocontrol agents are most commonly used in natural habitats.

The importance of any factor on persistence, or at least our specific desire for persistence, is really determined not only by the agent itself, but also by the intended use pattern of that agent. Each approach has different desired outcomes, quantitative aspects (e.g., efficacious amount, number of applications), specific mode of action (e.g., outright pathogenesis, competitive exclusion, induction of plant systemic resistance), degree and timing of control (short term catastrophic mortality versus long term population reduction to below an economic or action threshold). Classical biocontrol involves introduction of small to moderate numbers of an agent with the goal that it will reproduce, becoming established and even spread in an epizootic or epiphytotic. In a perfect biocontrol world, only one introduction would be needed and the agent's biological attributes would do the rest. Augmentative introductions of a microbial agent, seeking to change the population equilibria between target and microorganism to favor the latter and its effects on the target host population, are often several in a season. Inundative applications of a microorganism to a target crop or habitat commonly seek to overwhelm any disadvantages of the microbial with sheer numbers to cause catastrophic mortality of the target host, in a chemical paradigm, albeit a more environmentally safe one. Because of crop or target phenology, short term effects and thus persistence, are satisfactory. And repeat applications are even commercially desirable (repeat sales). The discovery of systemic acquired resistance (SAR), a "whole-plant" resistance response that occurs following an earlier localized exposure to a pathogen, analogous to the vertebrate innate immune system, and induced systemic resistance (ISR), largely mediated by jasmonic acid-dependent pathways, have introduced another significant approach in using organisms as biocontrol agents – inducing plant resistance, even to herbivorous insects, by simple exposure to the microbial agent. In this case persistence of the microbial agent may be of little concern.

The biological characteristics of a microorganism also determine persistence. Many arthropod pathogens are used via application of a dormant stage (conidium, cyst, spore, viral inclusion body) that acts only when introduced into the body of its target insect. These resting stages can be very exposed to deleterious environmental factors, e.g. UV radiation on the phylloplane, which confer a very short persistence. Even in the soil such arthropod control agents generally remain dormant until contact with a host insect. In contrast, some of the more successful weed-attacking, or plant pathogen-attacking microbes used in the soil, are readily adapted to grow and flourish in the soil, e.g., *Trichoderma harzianum* or *Laetisaria arvalis,* and can have natural, long persistence. Some plant pathogens, e.g., *Aphanomyces* can persist in a field for years. The biological characteristics can also show intraspecific variability to the extent that a candidate strain is chosen for characteristics superior of other of the same species.

Persistence of a microbial agent can also be prolonged by formulation and by fermentation variables to overcome agent weaknesses. Formulations can provide UV protection, allow spore germination at low humidities or offer required moisture for germination, flotation in aquatic habitats. Fermentation variables can be adjusted to cause greater inherent spore longevity, or ability to function at supra- or subnormal temperatures. But there are limitations to both approaches in extending persistence.

In summary, the consideration of persistence in assessing the risk of a microbial agent is very complex, and needs to consider the agent, its use pattern, and its habitat. I believe that in most cases persistence has to be evaluated on a case by case basis.